SJVDP Reports Library
Rm W-2212 ID No. 5628

SAN JOAQUIN VALLEY HYDROLOGIC AND SALT LOAD BUDGETS

Prepared
Under Contract For The
Federal-State
San Joaquin Valley
Drainage Program

OCTOBER 1988

LIBRARY COPY
SAN JOAQUIN VALLEY
DRAINAGE PROGRAM

This report presents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public health, (2) surface- and groundwater resources, (3) agricultural productivity, and (4) fish and wildlife resources.

Inquiries concerning the San Joaquin Valley Drainage Program may be directed to:

San Joaquin Valley Drainage Program
2800 Cottage Way, Room W-2143
Sacramento, California 95825-1898

SAT121/10

SAN JOAQUIN VALLEY

HYDROLOGIC AND SALT LOAD BUDGETS

Prepared for the
San Joaquin Valley Drainage Program
2800 Cottage Way, Room W-2143
Sacramento, CA 95825-1898

Under
U. S. Bureau of Reclamation
Contract No. 7-CS-20-05210
Order No. 8-PD-20-05210/003, Modification 003

By CH2M HILL
3840 Rosin Court, Suite 110
Sacramento, CA 95834

October 1988

CONTENTS

	Page
Executive Summary	iii
Introduction	1
Water and Salt Budgets	3
Results	7
Hydrologic Budgets	7
Mass Load Budgets	13
Implications for Management	15
Bibliography	19

Appendix A. Explanation of Water and Salt Budgets

Appendix B. Budget Table

Appendix C. Figures (C1-C5)

LIST OF TABLES

Number		
1	Calibration Parameters	6
2	San Joaquin Valley Key Hydrologic Budget Features	8
3	San Joaquin Valley Key Salt Budget Features	9

LIST OF FIGURES

1	San Joaquin Valley Drainage Program Planning Subareas	2
2	Conceptual Hydrologic Representation	4

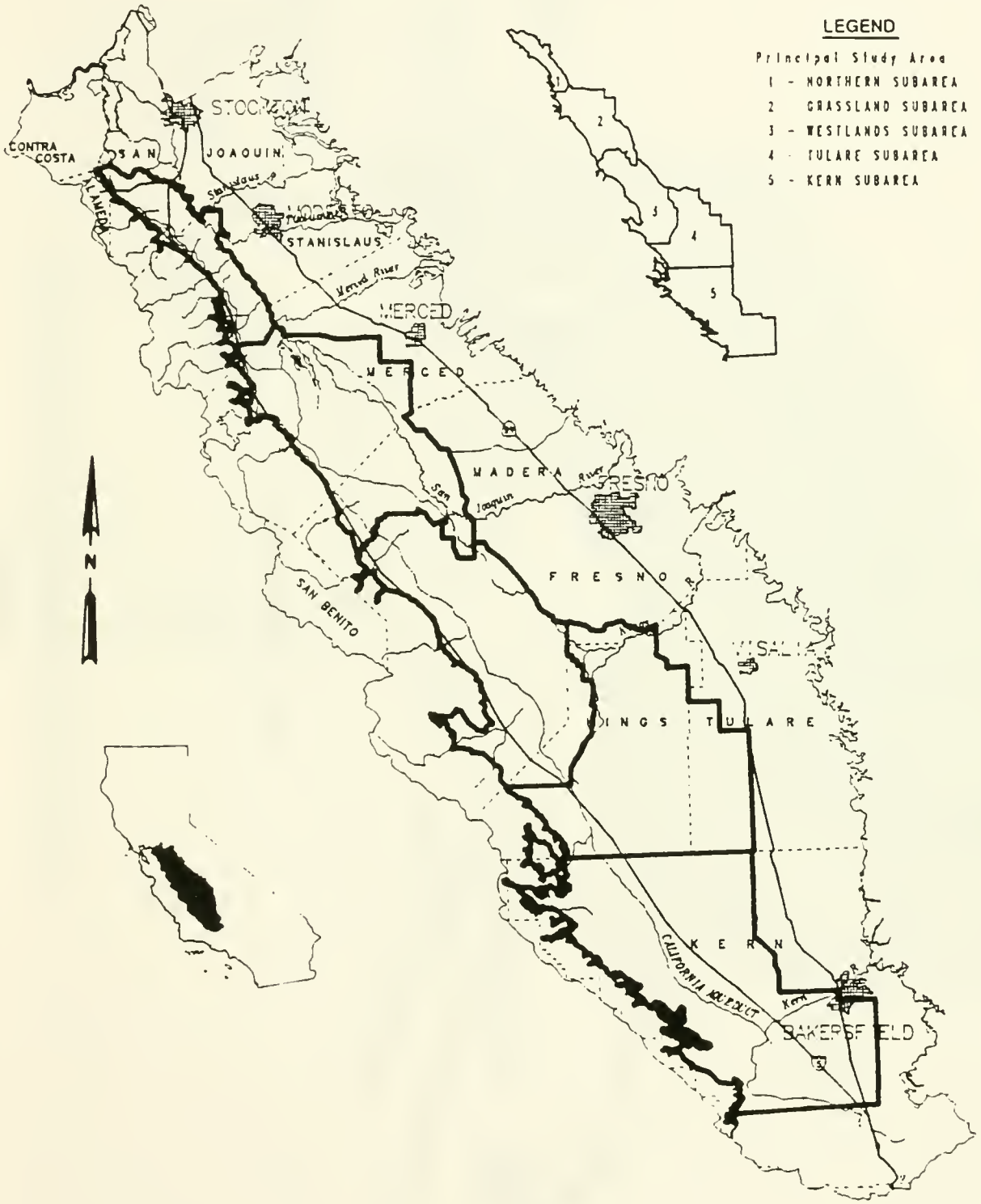
EXECUTIVE SUMMARY

A hydrologic imbalance in portions of the San Joaquin Valley causes groundwater levels to rise to the point that soils drainage and agricultural productivity are adversely affected. Current planning efforts by the Federal-State San Joaquin Valley Drainage Program are pursuing a variety of potential solutions to these problems. Reconnaissance level hydrologic and dissolved solids (salt) budgets representing existing average annual conditions were prepared for five subareas (see Figure 1) in order to provide a consistent, quantitative framework for the Drainage Program's planning efforts.

The budgets are based on a simplified representation of the hydrologic system (see Figure 2) and use existing data drawn from a wide variety of sources, including the data bases of the Department of Water Resources' Hydrologic and Economic Model and the U.S. Geological Survey's Regional Aquifer System Analysis model. The budgets show that the Northern and Grasslands subareas are near hydrologic balance in their unconfined aquifers. The Westlands, Tulare, and Kern subareas are gaining storage, causing groundwater levels to rise over time, gradually expanding the area of drainage-affected land.

FIGURE 1

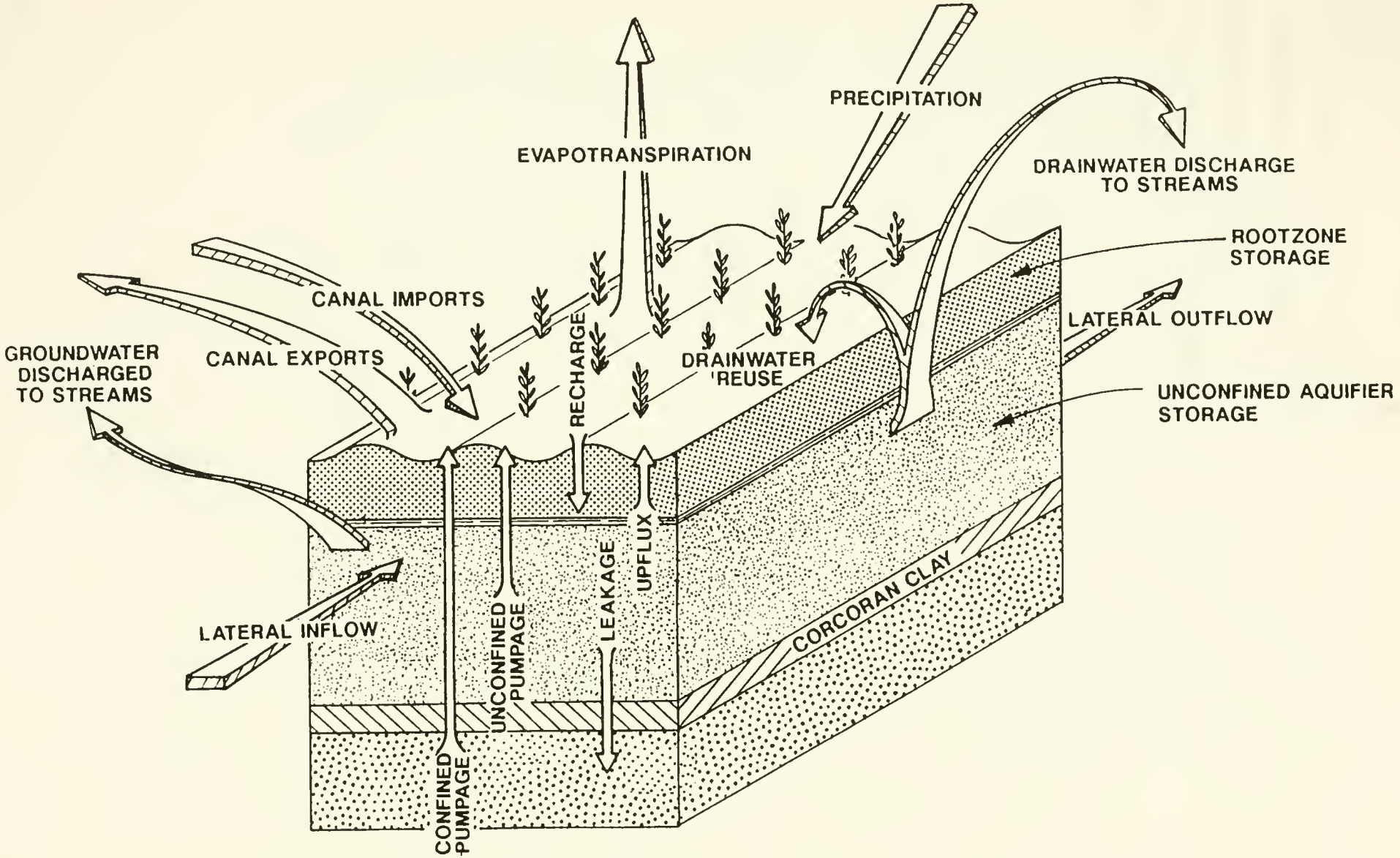
SAN JOAQUIN VALLEY DRAINAGE PROGRAM
PLANNING SUBAREAS



CH2M HILL

FIGURE 2

CONCEPTUAL HYDROLOGIC REPRESENTATION



CH2M HILL

It is concluded that the present hydrologic imbalances of the unconfined aquifers could be offset by the reduction of deep percolation of applied water and canal seepage (possible with existing technical capabilities). However, a salt imbalance would still exist, causing unconfined groundwater dissolved salt concentration to increase over time. Increasing surface water imports to the Westlands, Tulare, and Kern subareas to retire unconfined groundwater pumping would tend to increase surplus storage and accelerate the spread of drainage-affected areas.

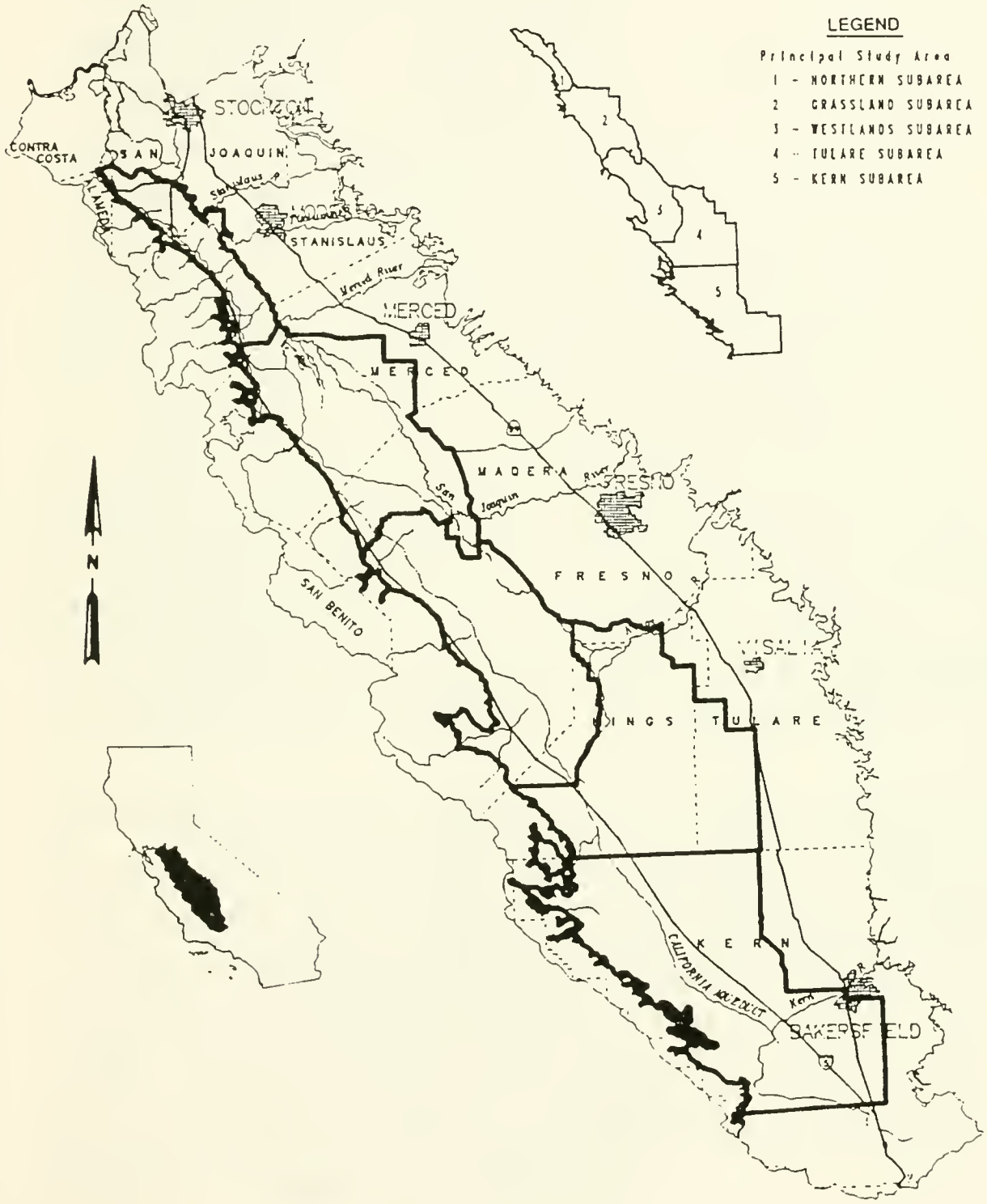
INTRODUCTION

A hydrologic imbalance in portions of the San Joaquin Valley causes groundwater levels to rise to the point that soils and agricultural productivity are adversely affected. Current planning efforts by the Federal-State San Joaquin Valley Drainage Program are pursuing a variety of potential solutions to the drainage problems, some involving source control, which reduces inflow to the groundwater system, and some aimed at disposal, which increases outflow from the groundwater system. Both kinds of solutions are designed to reduce the hydrologic imbalance and alleviate drainage problems. For planning purposes, the Drainage Program has divided the valley into the five subareas shown in Figure 1.

The objective of this study is to prepare reconnaissance level water and salt budgets that identify and quantify the principal flow paths of water and associated dissolved solids (salts) into and out of the five planning subareas. The water and salt budgets presented in this report represent existing average annual conditions in order to provide a consistent, quantitative framework for regional planning.

FIGURE 1

SAN JOAQUIN VALLEY DRAINAGE PROGRAM
PLANNING SUBAREAS



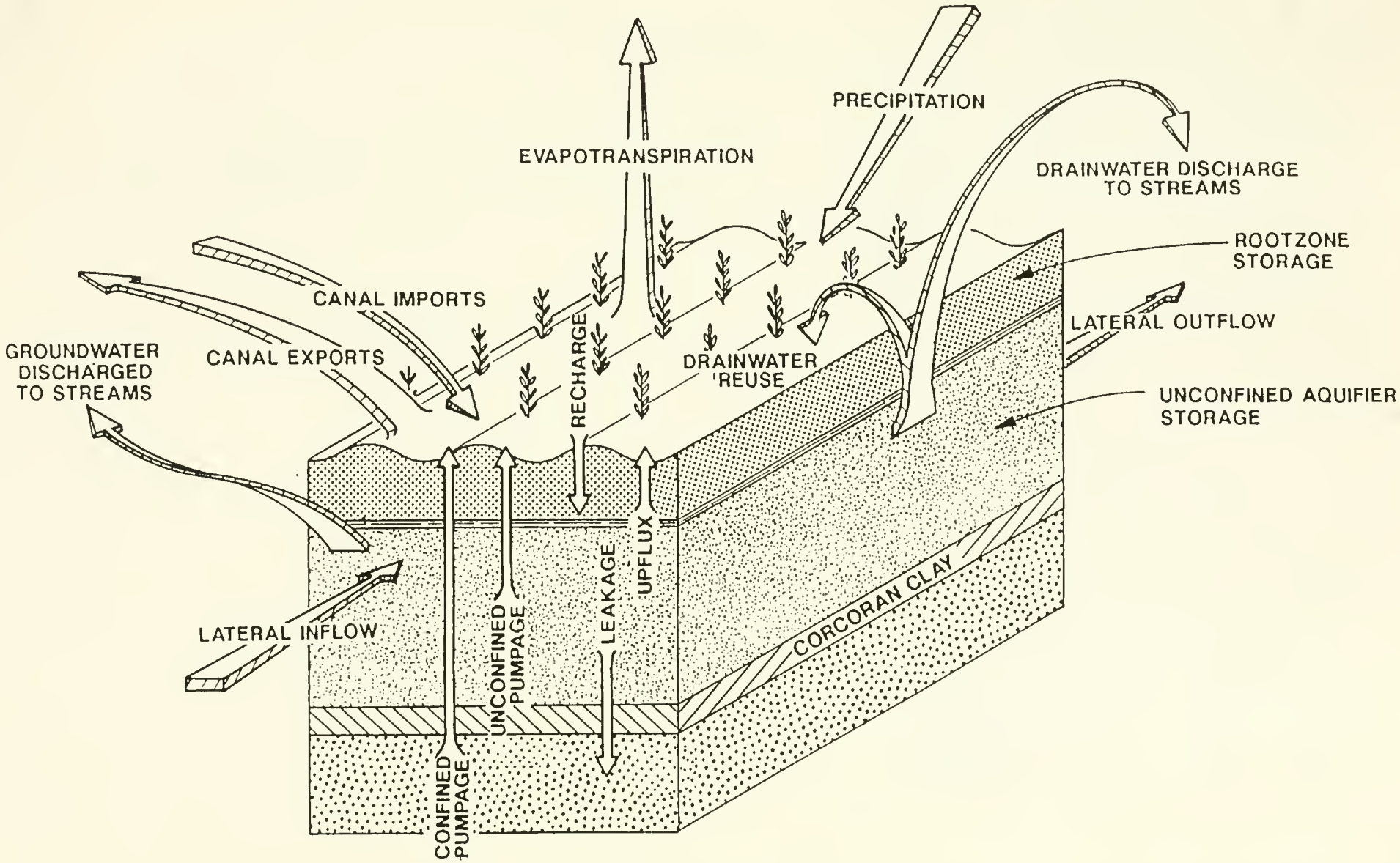
WATER AND SALT BUDGETS

The water and salt budgets are based on the simplified representation of the hydrologic system shown in Figure 2. The system is comprised of two subsystems, specifically, (1) the rootzone subsystem, which includes all surface water and subsurface water down to the free water table, and (2) the unconfined aquifer system, which includes all subsurface water below the free water table down to the Corcoran clay. Because shallow groundwater is the focus of drainage problems, the base of the unconfined aquifer was chosen as the lower boundary for this study. The occurrence of localized perched water tables within the unconfined aquifer is not addressed due to the regional scale of the parameters used. Two budgets were prepared for each subsystem: one for water and another for salts. Because water is the transport medium for salt, the salt budgets result from the hydrologic budgets, once salt concentrations have been specified.

The budgets are based largely on available published data with adjustments to reflect present conditions and different areal boundaries. The Department of Water Resources' (DWR) Hydrologic and Economic Model (HEM) database and the U.S. Geological Survey's (USGS) Regional Aquifer System Analysis (RASA) model database were used extensively. Budget items and associated data sources or computational procedures are described in detail in Appendix A.

FIGURE 2

CONCEPTUAL HYDROLOGIC REPRESENTATION



The water budgets were calibrated so that annual storage changes in the unconfined aquifer were approximately equal to independently computed values derived from observed changes in groundwater levels. In general, the calibration was achieved by adjusting the vertical rate of flow (leakance) through the Corcoran clay and/or the ratio of confined to unconfined pumping. Table 1 indicates the changes that were made to achieve the calibration. It is interesting to note that the average Corcoran clay leakances that result from the calibration agree reasonably well with results from other modeling efforts.

Table 1
CALIBRATION PARAMETERS

Subarea	Before Calibration: Change in Storage Thousand AF/yr	Before Calibration: Pumping Ratio (%)[1]	Before Calibration: Corcoran Clay Leakance Thousand AF/yr	After Calibration: Change in Storage Thousand AF/yr	After Calibration: Pumping Ratio (%)[1]	After Calibration: Corcoran Clay Leakance Thousand AF/yr	Change: Change in Storage (%)	Change: Pumping Ratio (%)	Change: Corcoran Clay Leakance (%)
North	91.2	53:47	-118	-4.4	53:47	-40	-105	No change	-66
Grasslands	11.6	51:49	200	1.9	65:35	200	-83	+27/-29	No change
Westlands	-245.8	50:50	435	24.7	50:50	300	+110	No change	-31
Tulare	-324.4	65:35	305	90.1	30:70	78	+128	-54/+50	-74
Kern	-1,041.8	43:57	1,479	186.8	55:45	189	+118	+28/-21	-87

[1]Pumping ratio is the ratio of pumping from the unconfined and confined aquifers, respectively. For example, 53:47 indicates that 53 percent of the total water pumped comes from the unconfined aquifer, and 47 percent from the confined.

RESULTS

The results of the water and salt budgets are shown in complete form in Table B-1 in Appendix B and are illustrated in simplified form in Figures C1 through C5 in Appendix C. Tables 2 and 3 summarize the important aspects of the water and salt budgets and provide the basis for this results discussion. Most of the discussion focuses on irrigation-related parameters because of their significance as a source of groundwater recharge. Per-acre values discussed are based on irrigated acreage unless otherwise noted.

HYDROLOGIC BUDGETS

WATER SUPPLY

Total water supply to the subareas varies significantly as does the ratio of surface water to groundwater use in the subareas. Grasslands receives the greatest per-acre water supply, averaging 3.20 acre-feet per irrigated acre, including 2.35 acre-feet per acre (73 percent) from surface supplies and 0.85 acre-foot per acre (27 percent) from groundwater. The Tulare subarea receives the least water, averaging only 2.26 acre-feet per acre, with 52 percent coming from surface sources and the remainder from groundwater.

Table 2
SAN JOAQUIN VALLEY
KEY HYDROLOGIC BUDGET FEATURES

	Units	Northern	Grasslands	Westlands	Tulare	Kern	Total
AREAS							
Irrigated Area	(1000Ac)	150.6	302.4	659.5	507.2	693.6	2313.3
Gross Area	(1000Ac)	231.9	511.0	791.8	641.4	1618.6	3794.7
WATER SUPPLY							
Surface Water	(TAF)	211.0	710.6	1396.0	599.0	1354.0	4270.6
	(AF/A)	1.40	2.35	2.12	1.18	1.95	1.85
Groundwater	(TAF)	170.3	257.8	155.9	549.8	506.9	1640.7
	(AF/A)	1.13	0.85	0.24	1.08	0.73	0.71
Total	(TAF)	381.3	968.4	1551.9	1148.8	1860.9	5911.3
	(AF/A)	2.53	3.20	2.35	2.26	2.68	2.56
CROP WATER REQUIREMENTS							
Total Crop ET	(TAF)	282.0	721.2	1352.3	1027.6	1456.1	4839.2
	(AF/A)	1.87	2.38	2.05	2.03	2.10	2.09
- from Precipitation	(TAF)	68.4	136.3	171.0	177.1	214.2	767.0
	(AF/A)	0.45	0.45	0.26	0.35	0.31	0.33
	(%)	24	19	13	17	15	16
- from Upflux	(TAF)	22.8	188.3	147.5	227.3	61.9	647.8
	(AF/A)	0.15	0.62	0.22	0.45	0.09	0.28
	(%)	8	26	11	22	4	13
- from Applied Water	(TAF)	190.8	396.6	1033.9	623.2	1180.0	3424.5
	(AF/A)	1.27	1.31	1.57	1.23	1.70	1.48
	(%)	68	55	76	61	81	71
UNCONFINED AQUIFER INFLOW							
Canal Seepage	(TAF)	58.0	243.0	48.0	298.0	228.0	875.0
	(AF/A)	0.39	0.80	0.07	0.59	0.33	0.38
Total Deep Percolation	(TAF)	138.3	345.5	490.7	267.3	444.4	1686.2
	(AF/A)	0.92	1.14	0.74	0.53	0.64	0.73
- from Applied Water	(TAF)	117.7	302.9	419.5	204.9	387.9	1432.9
	(AF/A)	0.78	1.00	0.64	0.40	0.56	0.62
	(%)	85	88	85	77	87	85
- from Precipitation	(TAF)	20.6	42.6	71.2	62.4	56.5	253.3
	(AF/A)	0.14	0.14	0.11	0.12	0.08	0.11
	(%)	15	12	15	23	13	15
Net Lateral Inflow	(TAF)	-3.0	5.0	-5.0	12.0	-5.0	4.0
UNCONFINED AQUIFER OUTFLOW							
Pumping	(TAF)	90.3	167.6	77.9	164.9	278.8	779.5
	(AF/A)	0.60	0.55	0.12	0.33	0.40	0.34
Total (Tile) Drainage Water	(TAF)	17.6	34.3	3.5	37.5	7.5	100.3
	(AF/A)	0.12	0.11	0.01	0.07	0.01	0.04
Upflux	(TAF)	22.8	188.3	147.5	227.3	61.9	647.8
	(AF/A)	0.15	0.62	0.22	0.45	0.09	0.28
Net Leakage (thru Corcoran Clay)	(TAF)	-40.0	200.0	300.0	78.0	189.0	727.0
	(AF/A)	-0.27	0.66	0.45	0.15	0.27	0.31
UNCONFINED AQUIFER STORAGE							
Annual Change	(TAF)	-4.4	1.9	24.7	90.1	186.8	299.1
	(AF/A)	-0.02	0.00	0.03	0.14	0.12	0.08
Rate of Watertable Ascent	(ft/yr)	-0.2	0.0	0.3	1.4	1.2	0.8

* All per-acre values in this table are based on irrigated acreage, except for annual change in aquifer storage, which is based on gross acreage.

Table 3
SAN JOAQUIN VALLEY
KEY SALT BUDGET FEATURES

	Units	Northern	Grasslands	Westlands	Tulare	Kern	Total
UNCONFINED AQUIFER INFLOW							
Canal Seepage	(1000 Tons)	33.9	118.9	16.3	64.8	35.3	269.2
	(%)	7	10	1	2	1	3
Evaporation Ponds	(1000 Tons)	0.0	0.6	41.5	517.1	184.6	743.8
	(%)	0	0	2	18	7	8
Streams	(1000 Tons)	0.0	0.0	53.0	1.0	37.8	91.8
	(%)	0	0	3	0	1	1
Deep Percolation of Applied Water	(1000 Tons)	361.9	742.7	862.4	1363.2	1351.9	4682.1
	(%)	71	64	49	47	53	53
Salt Dissolution	(1000 Tons)	36.0	214.0	777.0	896.0	899.0	2822.0
	(%)	7	18	44	31	35	32
Net Lateral Inflow	(1000 Tons)	-5.1	10.2	-13.6	32.6	-13.6	10.5
	(%)	-1	1	-1	1	-1	0
Other	(1000 Tons)	85.6	82.9	19.0	48.9	58.4	295.0
	(%)	17	7	1	2	2	3
Total	(1000 Tons)	512.3	1169.3	1755.6	2923.7	2553.5	8914.4
UNCONFINED AQUIFER OUTFLOW							
Pumping	(1000 Tons)	154.6	341.6	211.9	448.4	757.9	1914.3
	(%)	29	32	19	28	50	33
Streams	(1000 Tons)	307.3	20.7	0.0	77.1	0.0	405.1
	(%)	59	2	0	5	0	7
(Tile) Drainage Water	(1000 Tons)	47.8	278.7	61.9	802.5	199.6	1390.5
	(%)	9	26	6	50	13	24
Other	(1000 Tons)	15.4	424.1	840.0	266.4	543.7	2089.5
	(%)	3	40	75	17	36	36
Total	(1000 Tons)	525.1	1065.0	1113.7	1594.4	1501.2	5799.4
Unconfined Aquifer Storage							
Annual Change	(1000 Tons)	-6.0	110.4	666.4	1348.3	1082.3	3201.3

CROP WATER REQUIREMENTS

The Grasslands subarea has the highest unit crop evapotranspiration (ET) averaging 2.38 acre-feet per acre, which is 12 percent higher than the next highest subarea (Kern) and 21 percent higher than the adjoining Northern subarea. On a percentage basis, effective precipitation (crop ET from precipitation) is highest in the Northern subarea (24 percent) and lowest in Westlands (15 percent). Similarly, upflux, or the contribution to crop ET from shallow water tables, is largest in Grasslands (26 percent) and Tulare (22 percent), where extensive areas are underlain by shallow water tables. Upflux is least in the Kern subarea (4 percent). Finally, crop ET from applied water, which reflects irrigation efficiency, is highest in Kern (81 percent) and lowest in Grasslands (55 percent). This quantity reflects the efficiency with which irrigation water is applied on a subarea average basis. However, crop ET from applied water should be considered in conjunction with upflux to get a more representative picture of overall subarea irrigation efficiency because the majority of upflux water probably originated from deep percolation of applied water. If the percentages of crop ET from upflux and applied water are added for each subarea, the sum varies from a low of 76 (8+68) percent in the Northern subarea to a high of 87 (11+76) percent in

Westlands and averages 84 (13+71) percent for the whole area. These values probably are better indicators of subarea and regional irrigation efficiency.

UNCONFINED AQUIFER INFLOW

Canal seepage varies widely, from a low in Westlands of 48,000 acre-feet or 0.07 acre-foot per acre to a high in Grasslands of 243,000 acre-feet or 0.80 acre-foot per acre. Grasslands also has the largest deep percolation, averaging 1.16 acre-feet per irrigated acre, and Tulare has the least, averaging 0.55 acre-foot per acre. Deep percolation attributed to applied irrigation water ranges from 73 to 88 percent of total deep percolation. Net lateral inflow (inflow minus outflow) ranges from -5,000 to 12,000 acre-feet and is insignificant in the context of regional groundwater hydrology.

UNCONFINED AQUIFER OUTFLOW

Expressed on a unit basis, pumping of the unconfined aquifer is largest in the Northern subarea, averaging 0.60 acre-foot per acre, and is least in Westlands, averaging only 0.12 acre-foot per acre. Total tile drainage is about equal in the Northern and Grasslands subareas, averaging 0.12 and 0.11 acre-foot per acre, respectively, and is least in Westlands and

Kern, averaging only 0.01 acre-foot per acre. Tulare produces an average of 0.07 acre-foot per acre of tile drainwater. Upflux (also discussed under Crop Water Requirements) is included here to show its significance relative to other discharge paths out of the unconfined aquifer. In the Grasslands, Westlands, and Tulare subareas, upflux actually exceeds unconfined pumping. Finally, net leakage (downward flux) through the Corcoran clay is largest in Grasslands, averaging 0.66 acre-foot per acre (irrigated and nonirrigated) (0.66 foot per year) and is least in Tulare, averaging only 0.15 acre-foot per acre (0.15 foot per year). In the Northern subarea, there is a net upward movement of water through the Corcoran clay averaging 0.27 acre-foot per acre.

UNCONFINED AQUIFER STORAGE

The change in unconfined aquifer storage reflects the difference between inflow to and outflow from the groundwater system overlying the Corcoran clay. In a sense, it indicates the rate at which a potential drainage problem is developing or an existing problem is intensifying. The budgets indicate that the Northern and Grasslands subareas have negligible storage change, which is interpreted simply as indicating that groundwater systems are full and are emptying, through natural as well as manmade processes, as fast as they fill. In contrast, the Westlands, Tulare, and Kern

subareas are gaining storage, causing groundwater levels to rise over time. The estimated rates of rise for the three areas are 0.3, 1.3, and 1.1 feet per year, respectively.

MASS LOAD BUDGETS

UNCONFINED AQUIFER INFLOW

The various sources of salt inflow to the unconfined aquifer are presented in Table 3. The two primary sources are deep percolation of applied water, containing most of the salt imported with surface water and pumped with groundwater, and salt dissolution from the soil matrix. Deep percolation accounts for 47 to 71 percent of the total salt contribution; salt dissolution accounts for 7 to 44 percent. Note that the salt dissolution quantities represent existing average annual conditions and can be expected to decline over time as soils are reclaimed and soluble salts are reduced.

UNCONFINED AQUIFER OUTFLOW

The three principal salt discharge paths are pumping, natural discharge to streams, and tile drainage. The relative significance of each varies widely between subareas. It is important to remember that upflux provides

an outlet for water but not for salts; therefore, this process tends to cause shallow groundwater and soil salt concentrations to rise over time.

UNCONFINED AQUIFER STORAGE

The budgets indicate that only the Northern subarea has reached a salinity balance in the groundwater. All other subareas are gradually accumulating dissolved salts in the unconfined aquifer. This includes the Grasslands subarea, which is otherwise in hydrologic balance.

IMPLICATIONS FOR MANAGEMENT

The subarea water and salt budgets provide some insight for managing the drainage problem. The following conclusions and suggestions for management are based on the basic premise that the primary goals of management are to sustain agriculture and avoid unlawful or unwise damage to the environment or nonagricultural water users. Because these statements are based on the previously described budgets, they are subject to the assumptions and analytical structure used for those budgets. Consequently, the statements tend to overgeneralize an extremely complex physical system. However, they may be useful guidelines for regional and policy planners.

1. The Northern and Grassland subareas are currently at hydrologic equilibrium with water inflows matched by outflows. This implies that the extent of drainage-affected land should not change much over time as long as existing pumping levels are maintained and drainage systems continue to discharge to surface waterways. Reclaiming existing drainage-affected lands would require increased outflows from the unconfined aquifer, either through increased pumping (depending on hydrology) or artificial drainage.

2. Considered on a regional basis, the Westlands, Tulare, and Kern subareas are out of hydrologic balance. More water flows into the unconfined aquifer than flows out, causing water tables to rise and, consequently, gradually increase the extent of drainage-affected lands.

3. The rate of water table ascent is not equal in the Westlands, Tulare, and Kern subareas. Spread across the total acreage of each subarea, the rate at which the water table is rising is: Westlands, 0.3 foot per year; Tulare, 1.3 foot per year; and Kern, 1.1 foot per year.

4. Management of drainage problems can be considered from two perspectives: 1) Managing the accumulated hydrologic imbalance and, 2) managing the annual imbalance. The existing drainage condition, measured in terms of the extent of drainage-affected land, reflects the accumulation of many years of surplus water in unconfined aquifer storage. In contrast, the rate at which water table elevations are rising reflects the annual increase in unconfined aquifer storage. From a management perspective, reclaiming existing drainage-affected lands requires releasing from storage a large accumulation of saline, shallow groundwater. This is a significant but not impossible task. A more realistic initial object-

tive should be to manage toward hydrologic balance so that the rate of deterioration is slowed and eventually stopped.

5. The present hydrologic imbalances of the unconfined aquifers in the Westlands, Tulare, and Kern areas could be offset by relatively modest improvements in irrigation technology and canal lining. For example, the following changes would achieve hydrologic balance, all other factors remaining constant:

Deep Percolation of Applied Water (% of Applied Water)	Westlands	Tulare	Kern
Existing	27	18	21
Balanced	25	15	15
% Reduction	7	17	29
Canal Seepage (Thousand ac-ft/yr)			
Existing	48	298	228
Balanced	48	240	150
% Reduction	none required	19	34

These improvements are reasonably achievable on a regional basis with available, proven technology. However, it should be recognized that establishing hydrologic balance would not also achieve salt balance. Even with hydrologic balance, dissolved salts would be accumulating in the unconfined aquifer over time.

6. Pumping from the unconfined aquifer is a critical element in the hydrologic balance. It provides a manageable outlet from the aquifer, in effect, acting like a giant reuse system. Increased unconfined pumping, where possible, in conjunction with surface water blending to mitigate poor groundwater quality, should be considered as a short- to medium-term management alternative. Eventually, however, unconfined groundwater may become so saline that it will be unsuitable for irrigation, even with blending. At this point, additional solutions will be required to achieve hydrologic balance. Conversely, increased surface water imports for the purpose of retiring costly and poor-quality unconfined groundwater pumping would tend to increase the surplus storage and accelerate the spread of drainage-affected areas.

7. Where unconfined pumping can be clearly shown to improve soil drainage by lowering groundwater levels, no additional surface water supplies should be provided for the purpose of retiring pumping.

8. Upflux, or the capillary rise of water into the root zone and use by plants, is also a critical element in the hydrologic balance. Current efforts to make these processes more controllable (e.g., controlled drainage) are very appropriate.

BIBLIOGRAPHY

Belitz, Kenneth. 1988. Character and Evolution of the Ground-Water Flow System in the Central Part of the Western San Joaquin Valley. Open-File Report 87-573. Sacramento, California: U. S. Geological Survey, in cooperation with the San Joaquin Valley Drainage Program. 1988.

Boyle Engineering Corporation. 1986. Evaluation of On-Farm Agricultural Management Alternatives. Prepared for the San Joaquin Valley Drainage Program. Fresno, California. October 1986.

Brown and Caldwell Consulting Engineers. 1987. San Joaquin Valley Drainage Program Regional Agricultural Production Model. Prepared for San Joaquin Valley Drainage Program, U. S. Department of Interior Bureau of Reclamation. Sacramento, California. August 1987.

Brown, Kirk W. et al. 1978. Development of Management Guidelines to Prevent Pollution by Irrigation Return Flow from Rice Fields. EPA-600/2-78-082. Ada, Oklahoma: Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency. April 1978.

California Department of Water Resources. 1988a. Division of Planning. Investigation of Evaporative Ponds for the Disposal of Agricultural Drainage in the San Joaquin Valley. Progress Report. May 1988.

———. 1988b. San Joaquin District. SWAM User Manual, Version AO. Memorandum Report. January 1988.

———. 1986. Crop Water Use in California. Bulletin 113-4. Sacramento, California. April 1986.

———. 1985. Ground Water Study, San Joaquin Valley. Third Progress Report. September 1985.

———. 1982. Hydrologic-Economic Model of the San Joaquin Valley. Bulletin 214. December 1982.

———. 1981. Ground Water Study, San Joaquin Valley. Second Progress Report. June 1981.

———. 1975. Vegetative Water Use in California, 1974. Bulletin No. 113-3. Sacramento, California. April 1975.

———————. Irrigation Water Use in the Central Valley of California. Sacramento, California. No date.

California Regional Water Quality Control Board. 1988. Beneficial Use Assessment per State Water Resources Control Board Order WQ 87-3. Sacramento, California. January 1988.

California State Water Resources Control Board. 1987. Regulation of Agricultural Drainage to the San Joaquin River. Revised Draft Executive Summary. July 1987.

CH2M HILL and David De Bruyn. 1985. Drainage Review and Appraisal--San Joaquin Valley Conveyance Investigation. Prepared for U. S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region. Sacramento, California. November 1985.

Diamond, Jonathan and Alex K. Williamson. 1983. Summary of Ground-Water Pumpage in the Central Valley. Water Resources Investigations Report 83-4037. Sacramento, California: U. S. Geological Survey. October 1983.

Dudek, Daniel J. and Gerald L. Horner. 1985. Integrated Physical- Economic Resource Analysis: A Case Study of the San Joaquin Valley. Ada, Oklahoma: Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U.S. Environmental Protection Agency.

Gaines, Raymond W. 1988. West San Joaquin Valley Agricultural Setting. Prepared for the San Joaquin Valley Drainage Program. Sacramento, California. June 1988.

Gilliom, Robert J. and Daphne G. Clifton. 1987. Organochlorine Pesticide Residues in Bed Sediments of the San Joaquin River and Its Tributaries. Open File Report 87-531. Prepared in cooperation with the San Joaquin Valley Drainage Program. Sacramento, California: U. S. Geological Survey.

Grismer and Gates. 1988. "Estimating Saline Water Table Contributions to Crop Water Use for Irrigation-Drainage System Design." California Agriculture. 42(2):23-24.

Jensen, Marvin E. 1975. Scientific Irrigation Scheduling for Salinity Control of Irrigation Regurn Flows. EPA-600/2-75-064. Ada, Oklahoma: Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency. November 1975.

McLaughlin, Dennis. 1982. User's Manual for the San Joaquin Groundwater Model (GWM). Prepared for California Department of Water Resources. Lafayette, California. Revised November 1982.

National Oceanic and Atmospheric Administration. 1982. Evaporation Atlas for the Contiguous 48 United States. Washington, D.C. June 1982.

Orlob, G. T. 1987. Modeling the Impacts of Salinization in an Estuarial Environment. Presented at the 17th International Wasserbau Seminar. Aachen, West Germany. January 6, 1987.

San Joaquin Valley Agricultural Water Committee. 1979. Water Resources Management in the Southern San Joaquin Valley, California. Fresno, California. January 1979.

San Joaquin Valley Drainage Program. 1988. Formulation and Evaluation of Agricultural Drainage Water Management Plans for the San Joaquin Valley. Draft Technical Report. May 1988.

————————. 1987. Developing Options: An Overview of Efforts to Solve Agricultural Drainage and Drainage- Related Problems in the San Joaquin Valley. Sacramento, California. December 1987.

————————. 1987. On-Farm and Wetland Management Practices. Summary of Workshops in Mendota and Hanford, California, February 1987. Sacramento, California.

Smith, Gregory Read. 1985. Evaluation of On-Farm Evaporation Ponds. Davis, California.

South Australian Department of Agriculture. 1981. South Australian Riverland Alternative Irrigation System Adoption Survey Questionnaire. Adelaide, Austrialia: South Australian Department of Agriculture Extension Research and Evaluation Unit. January/February 1981.

U. S. Bureau of Reclamation. 1987. Water Quality Analyses--West Side- San Joaquin Valley. Sacramento, California. July 1987.

————————. 1986. Kesterson Program Final Environmental Impact Statement. Volume II. Prepared in cooperation with U. S. Fish and Wildlife Service and U. S. Army Corps of Engineers. Sacramento, California. October 1986.

U. S. Department of Agriculture River Basin - Watershed Planning Staff. 1973. Soil Group Areas, 1972. Berkeley, California. March 1973.

Westlands Water District. 1987. 1985-86 Water Conservation and Management Program Review and Evaluation. Fresno, California. May 1987.

———————. 1986. Facts & Figures. Fresno, California.

———————. 1985. Water Conservation and Management Handbook. Fresno, California. January 1985.

Wierenga, Peter J. 1977. Influence of Trickle and Surface Irrigation on Return Flow Quality. EPA-600/2-77-093. Ada, Oklahoma: Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency. May 1977.

Willardson, Lyman S. and R. John Hanks. 1976. Irrigation Management Affecting Quality and Quantity. EPA-600/2-76-226. Ada, Oklahoma: Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency. September 1976.

Williamson, Alex K., David E. Prudic, and Lindsay A. Swain. 1985. Ground-Water Flow in the Central Valley, California. Open-File Report 85-345. Sacramento, California. U. S. Geological Survey.

Appendix A

EXPLANATION OF WATER AND SALT BUDGETS

Appendix A

EXPLANATION OF WATER AND SALT BUDGETS

ROOT ZONE WATER BUDGET

INFLOWS

Water for the root zone budget of each subarea comes from precipitation, surface inflow, pumping of the unconfined and confined aquifers, and groundwater discharge.

Precipitation

Long-term mean annual precipitation data (DWR 1985) were weighted by area to give total gross precipitation for each subarea. The total was divided by land use into precipitation on irrigated land, nonirrigated land, refuges/wetlands, evaporation ponds, and M&I/urban areas.

Surface Inflow

Movement of surface water has been analyzed in detail by the DWR (1985, 1988b) for a calibration period between 1970-1982. The major component of surface water inflow is canal inflow, which has been separated into inflows to irrigated lands and inflows to refuges/wetlands, based on the water requirements

of the latter. Canal inflows include water diverted from local streams and rivers as well as imported water. Inflow from minor streams includes water from small drainages that entirely percolates to the groundwater. River flows that pass through a subarea are not included in the budgets.

Pumping of the Unconfined and Confined Aquifers

Computations of the quantity of water pumped from the unconfined aquifer for irrigation was based on requirements of the crops. The total agricultural pumping requirement (unconfined and confined) was computed as the applied water evapotranspiration (ET) divided by onfarm efficiency plus canal outflows, canal evaporation, and canal leakage, minus agricultural reuse and canal inflows. The total agricultural pumping requirement was divided between the unconfined and confined aquifer based on data from the USGS Regional Aquifer System Analysis (RASA) model (Williamson et al. 1985).

Pumping for M&I needs was computed from the USGS model data for the calibration period 1961-1977 (Williamson et al. 1985). Demands for current conditions (1988) were computed by extrapolation of the USGS data. All M&I pumping was assumed to be from the confined aquifer.

Groundwater Discharge

The term groundwater discharge in this report refers to all water that is transferred from the unconfined aquifer to the surface or root zone by means other than pumping. Groundwater discharge to streams consists of river accretions taken from the DWR data (1985, 1988b). Groundwater discharge to drains was divided into agricultural reuse, stream outflow, and evaporation pond components.

Agricultural reuse and stream outflow components for Westlands, Tulare, and Kern were taken from estimates supplied by the Drainage Program. Groundwater discharge to streams for the North subarea was taken from DWR data (1985, 1988b); groundwater discharge for the Grasslands subarea came from data in a State Water Resources Control Board publication (1987). A 50-50 split was assumed between agricultural reuse and discharge to streams for this value.

Groundwater discharge to evaporation ponds was estimated from DWR data (1988a).

Groundwater discharge to consumptive use consists of capillary upflux of water that is directly used by crops. This was computed using a relationship between upflux, depth to water table, total ET, and soil type (Grismer and Gates 1988). Areas of shallow groundwater came from maps compiled by the

Drainage Program. Since areas of shallow groundwater correspond with irrigated lands, refuges, and wetlands, an upflux component for nonirrigated areas was not included.

OUTFLOWS

Outflows from the root zone budget for each subarea include evapotranspiration/CU, evaporation, surface outflow, leakage, and deep percolation.

Evapotranspiration/CU

Evapotranspiration/CU (ET) requirements were computed based on four land use categories: irrigated lands, nonirrigated lands, refuges/wetlands, and M&I/urban areas. ET from irrigated lands was based on Westlands Water District (WWD) ET requirements combined with DWR 1980 land use data taken from the SWAM model database. WWD ET requirements were used directly for the Westlands subarea and were adjusted for the other subareas based on ratios of observed pan evaporation. ET requirements were derived from three sources: precipitation, upflux from shallow water tables, and applied water. Effective precipitation was based on WWD estimates in its water management handbook (1985) with adjustments made for the four subareas outside of Westlands. Contributions from upflux were computed using the same algorithm as is used by

the WADE model (Grismer and Gates 1988). ET not supplied from precipitation and upflux was assumed to come from applied water.

ET from nonirrigated lands was set equal to precipitation occurring on those lands, the assumption being that no deep percolation occurs in these areas.

ET from wetlands was included in the Grasslands subarea only. Estimates were based upon land use derived from a variety of sources, including the San Joaquin Valley Drainage Program. The same procedure of meeting ET from precipitation, upflux, and applied water was used for these areas.

Finally, consumptive use in urban areas was taken directly from the SWAM database.

Evaporation

Evaporation losses were included for the same four land use types as for ET (see preceding section), plus evaporation ponds and canals. Evaporation from irrigated lands was derived from precipitation and applied water. Evaporation from nonirrigated lands was set equal to zero in all subareas because ET was assumed to offset all precipitation occurring in these areas, as previously explained. Evaporation from wetland areas occurs primarily from free water surfaces. Estimates of free water surface evaporation rates

were taken from maps published by the National Oceanic and Atmospheric Administration (NOAA) (1982). These were combined with areas of free water surface reported for the refuges and wetland areas to get total evaporation. Evaporation from evaporation ponds was computed using the same NOAA rates applied to pond surface areas reported by DWR (1988a). Losses to evaporation from canal surfaces were taken directly from the SWAM database. Finally, evaporation losses from urban land use areas were assumed to be negligible.

Surface Outflow

Surface outflows from a subarea were divided into canal outflows (spills and exports), stream outflows (stream and river accretions while flowing through a subarea), and drain outflows. Canal outflows were taken from DWR data (1985, 1988a). Stream and drain outflows are equal to like components described on page A-3.

Leakage

Leakage from canals, streams and drains was computed from DWR data (1985, 1988b) as was leakage from evaporation ponds (1988a). Leakage from minor streams is equal to that discussed on page A-1.

Deep Percolation

Deep percolation was accounted for according to land use category, namely, irrigated land, nonirrigated land, refuges/ wetlands, and M&I/urban areas. Deep percolation from irrigated lands is clearly the most significant. It was determined as a fraction of the volume of water applied, with the fraction derived from irrigation system evaluation data from WWD, including appropriate adjustments for use in other subareas.

UNCONFINED AQUIFER WATER BUDGET

INFLOWS

Subsurface inflows from leakage and deep percolation mirror values described above under "Outfalls." Subsurface inflows from adjacent areas were computed using the Darcy equation based on aquifer properties from the DWR (1985) and McLaughlin (1982) and water table elevations from DWR depth-to-water-table measurements, DWR maps, and computer input (McLaughlin 1982).

Subsurface inflows from the confined aquifer were also computed using the Darcy equation. Vertical leakances were taken from the USGS RASA data (Williamson et al. 1985), and

confined aquifer piezometric heads from DWR maps and computer input (McLaughlin 1982).

OUTFLOWS

Subsurface outflows from pumpage and groundwater discharge mirror values described on pages A-1 to A-3. Subsurface outflows to adjacent areas and the confined aquifer were computed in the same manner as described on page A-7.

SALT BUDGETS

Salt inflow and outflow components of the salt budgets of each subarea were computed from known or estimated total dissolved solids concentrations of the components. The salt budget logic parallels the water budget; for example, salt leaving the root zone budget as leakage is equal to salt entering the unsaturated aquifer budget as leakage. Values in the salt budgets that were computed by other means are described below.

Leakage from Evaporation Ponds: Mass is equal to the volume of water leaking from evaporation ponds times the concentration of the pond water.

Deep Percolation of Applied Water from Irrigated Lands: Mass is equal to the sum of the masses of canal inflows, unconfined and confined pumpage, and groundwater discharge to agricultural reuse, minus canal outflows and canal leakages.

Deep Percolation of Salt Dissolution from Irrigated Lands: Deep percolation of applied water dissolves salts from the root zone that are carried to the unconfined aquifer. This is an input parameter.

Deep Percolation of Applied Water from Refuges/ Wetlands: Mass is equal to the sum of the masses of canal inflows, unconfined and confined pumpage.

Appendix B

HYDROLOGIC AND SALT BUDGET RESULTS

PROCESSES	WATER BUDGET (IN 1000 ACRE-FT)					TDS (IN MG/L)					SALT LOADING (IN 1000 TONS)				
	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN
Inflow to Surface															
Gross Precipitation															
Irrigated Lands	119.0	238.9	323.2	319.5	360.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-irrigated Land	63.0	115.6	65.5	79.4	489.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/wetlands	0.0	56.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation Ponds	0.0	0.1	0.2	2.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surface Inflow from															
Canals to Irrigated Lands	266.0	932.6	1400.0	600.0	1371.0	480.0	335.0	285.0	210.0	165.0	173.5	424.6	542.3	171.3	307.5
Canals to Refuges/wetlands	0.0	131.4	0.0	0.0	0.0	0.0	335.0	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0
Minor Streams	0.0	0.0	10.0	5.0	27.0	0.0	0.0	3900.0	150.0	1030.0	0.0	0.0	53.0	1.0	37.8
Pumping of the Unconfined															
Irrigated Lands	90.3	167.6	77.9	164.9	278.8	1260.0	1500.0	2000.0	2000.0	2000.0	154.6	341.6	211.9	448.4	757.9
Refuges/wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumping of the Confined															
Irrigated Lands	80.0	90.2	77.9	384.9	228.1	1000.0	1000.0	1000.0	1000.0	1000.0	108.8	122.6	105.9	523.1	310.1
Refuges/wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	18.0	12.0	14.0	23.0	43.0	1000.0	1000.0	1000.0	1000.0	1000.0	24.5	16.3	19.0	31.3	58.4
Excess Applied Fertilizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0	0.0	0.0	0.0	0.0
GW Discharge to															
Streams	119.0	8.0	0.0	4.0	0.0	1900.0	1900.0	0.0	14190.0	0.0	307.3	20.7	0.0	77.1	0.0
Drains															
Agricultural Reuse	0.0	17.0	1.5	14.0	1.0	0.0	6000.0	10000.0	15000.0	11000.0	0.0	138.6	20.4	285.4	15.0
Stream Outflow	17.6	17.1	0.0	0.0	0.0	2000.0	6000.0	0.0	0.0	0.0	47.8	139.4	0.0	0.0	0.0
Evaporation Ponds	0.0	0.2	2.0	23.5	6.5	0.0	2700.0	15650.0	16190.0	20900.0	0.0	0.6	41.5	517.1	184.6
Consumptive Use															
Irrigated Areas	22.8	188.3	147.5	227.3	61.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/wetlands	0.0	30.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL INFLOW TO SURFACE	795.7	2006.4	2119.7	1848.4	2868.2						816.5	1264.3	994.0	2054.7	1671.3
Outflow from Surface															
Evapotranspiration/CU															
Irrigated Lands															
Effective Precipitation	68.4	136.3	171.0	177.1	214.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shallow GW Contribution	22.8	188.3	147.5	227.3	61.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Applied Water	190.8	396.6	1033.9	623.2	1180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	282.0	721.2	1352.3	1027.6	1456.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PROCESSES	WATER BUDGET (IN 1000 ACRE-FT)					TDS (IN MG/L)					SALT LOADING (IN 1000 TONS)				
	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN
Non-irrigated Land	63.0	115.6	65.5	79.4	489.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/wetlands															
Effective Precipitation	0.0	25.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shallow GW Contribution	0.0	30.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Applied Water	0.0	72.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban CU	6.0	4.0	4.7	7.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation															
Irrigated Lands															
Of Precipitation	30.0	60.0	81.0	80.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Of Applied Water	9.5	21.6	45.0	25.6	48.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-irrigated Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/wetlands															
Of Precipitation	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Of Applied Water	0.0	49.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation Ponds	0.0	0.1	1.7	22.2	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canals	5.3	21.3	7.0	11.1	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Outflow from															
Canals	55.0	222.0	4.0	1.0	17.0	550.0	550.0	335.0	80.0	135.0	41.1	166.0	1.8	0.1	3.1
Streams	119.0	8.0	0.0	4.0	0.0	1900.0	1900.0	0.0	14190.0	0.0	307.3	20.7	0.0	77.1	0.0
Drains	17.6	17.1	0.0	0.0	0.0	2000.0	6000.0	0.0	0.0	0.0	47.8	139.4	0.0	0.0	0.0
Leakage from															
Canals, streams, and drains	58.0	243.0	48.0	298.0	228.0	430.0	360.0	250.0	160.0	114.0	33.9	118.9	16.3	64.8	35.3
Evaporation Ponds	0.0	0.1	0.5	4.2	0.9	0.0	4320.0	64930.9	90586.9	157965.1	0.0	0.6	41.5	517.1	184.6
Minor Streams	0.0	0.0	10.0	5.0	27.0	0.0	0.0	3900.0	150.0	1030.0	0.0	0.0	53.0	1.0	37.8
Deep Percolation															
Irrigated Lands															
Applied Water	117.7	302.9	419.5	204.9	387.9	2262.9	1804.2	1512.3	4895.3	2564.0	361.9	742.7	862.4	1363.2	1351.9
Rainfall	20.6	42.6	71.2	62.4	56.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Excess Fertilizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0	0.0	0.0	0.0	0.0
Salt Dissolution	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36.0	214.0	777.0	896.0	899.0
Non-irrigated Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/wetlands															
Applied Water	0.0	9.8	0.0	0.0	0.0	0.0	4491.7	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0
Rainfall	0.0	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	12.0	8.0	9.3	15.3	28.7	1500.0	1500.0	1500.0	1500.0	1500.0	24.5	16.3	19.0	31.3	58.4
TOTAL OUTFLOW FROM SURFACE	795.7	2006.4	2119.7	1848.4	2868.2						852.5	1478.3	1771.0	2950.7	2570.3

PROCESSES	WATER BUDGET (IN 1000 ACRE-FT)					TDS (IN MG/L)					SALT LOADING (IN 1000 TONS)				
	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN
Inflow to Subsurface															
Leakage from															
Canals, streams, and drains	58.0	243.0	48.0	298.0	228.0	430.0	360.0	250.0	160.0	114.0	33.9	118.9	16.3	64.8	35.3
Evaporation Ponds	0.0	0.1	0.5	4.2	0.9	0.0	4320.0	64930.9	90586.9	157965.1	0.0	0.6	41.5	517.1	184.6
Minor Streams	0.0	0.0	10.0	5.0	27.0	0.0	0.0	3900.0	150.0	1030.0	0.0	0.0	53.0	1.0	37.8
Deep Percolation															
Irrigated Lands															
Applied Water	117.7	302.9	419.5	204.9	387.9	2262.9	1804.2	1512.3	4895.3	2564.0	361.9	742.7	862.4	1363.2	1351.9
Rainfall	20.6	42.6	71.2	62.4	56.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Excess Fertilizer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0	0.0	0.0	0.0	0.0
Salt Dissolution	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36.0	214.0	777.0	896.0	899.0
Non-irrigated Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuges/Wetlands															
Applied Water	0.0	9.8	0.0	0.0	0.0	0.0	4491.7	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0
Rainfall	0.0	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	12.0	8.0	9.3	15.3	28.7	1500.0	1500.0	1500.0	1500.0	1500.0	24.5	16.3	19.0	31.3	58.4
Subsurface Flow from															
Adjacent areas	1.0	8.0	4.0	19.0	6.0	1260.0	1500.0	2000.0	2000.0	2000.0	1.7	16.3	10.9	51.6	16.3
Confined Aquifer	45.0	5.0	0.0	13.0	0.0	1000.0	1000.0	1000.0	1000.0	1000.0	61.2	6.8	0.0	17.7	0.0
TOTAL INFLOW TO SUBSURFACE	254.3	639.0	562.6	621.8	735.0						519.1	1175.4	1780.1	2942.7	2583.5

SAN JOAQUIN VALLEY SUBAREA WATER AND SALT BUDGETS

28-Sep-88

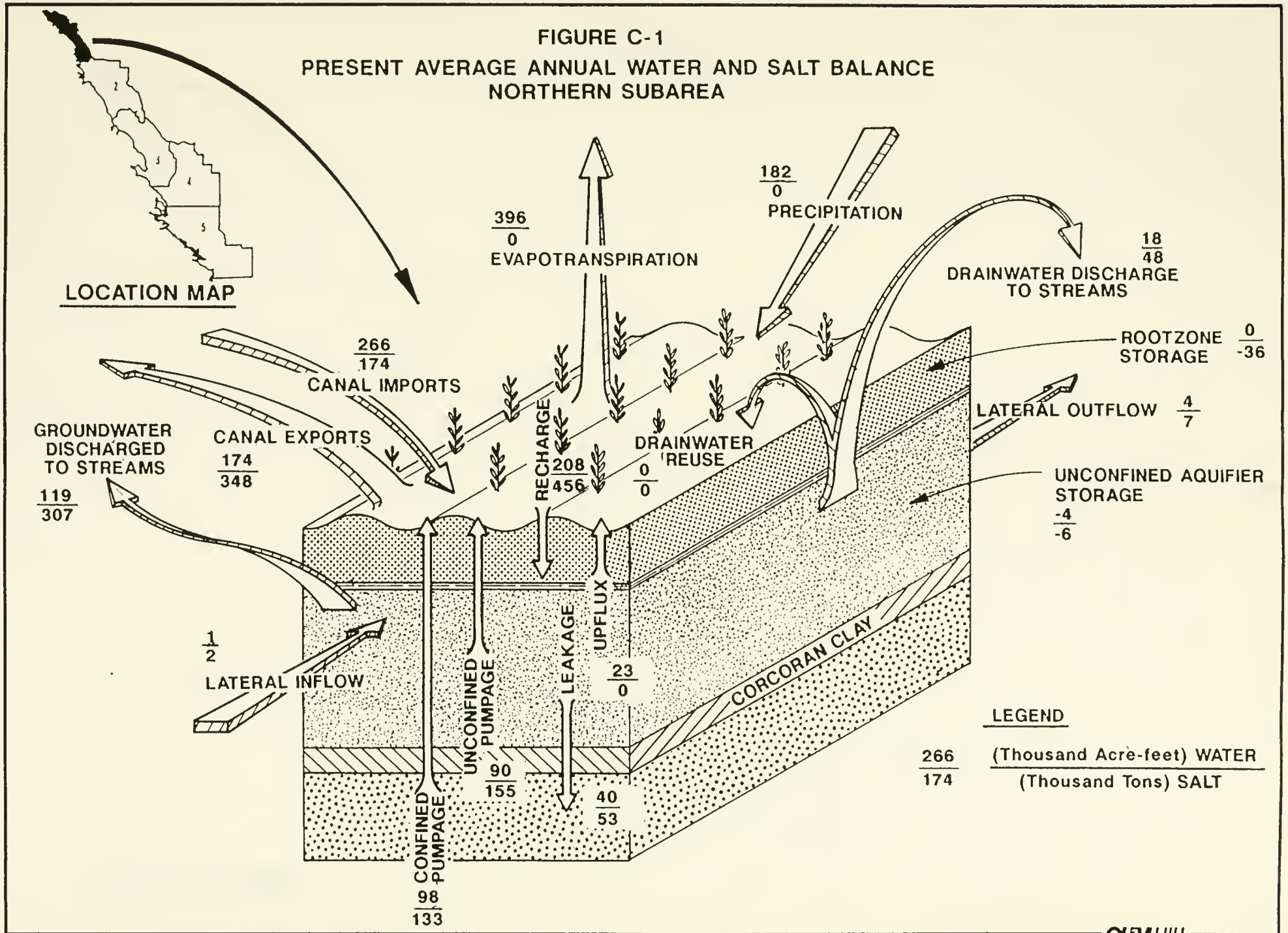
PROCESSES	WATER BUDGET (IN 1000 ACRE-FT)					TDS (IN MG/L)					SALT LOADING (IN 1000 TONS)				
	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN	NORTH	GRASSLANDS	WESTLANDS	TULARE	KERN
Outflow from Subsurface															
Pumping of the Unconfined															
Irrigated Lands	90.3	167.6	77.9	164.9	278.8	1260.0	1500.0	2000.0	2000.0	2000.0	154.6	341.6	211.9	448.4	757.9
Refuges/wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M&I/Urban Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GW Discharge to															
Streams	119.0	8.0	0.0	4.0	0.0	1900.0	1900.0	0.0	14190.0	0.0	307.3	20.7	0.0	77.1	0.0
Drains															
Agricultural Reuse	0.0	17.0	1.5	14.0	1.0	0.0	6000.0	10000.0	15000.0	11000.0	0.0	138.6	20.4	285.4	15.0
Stream Outflow	17.6	17.1	0.0	0.0	0.0	2000.0	6000.0	0.0	0.0	0.0	47.8	139.4	0.0	0.0	0.0
Evaporation Ponds	0.0	0.2	2.0	23.5	6.5	0.0	2700.0	15650.0	16190.0	20900.0	0.0	0.6	41.5	517.1	184.6
Consumptive Use															
-Irrigated Areas	22.8	188.3	147.5	227.3	61.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-Refuges/wetlands	0.0	30.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subsurface Flow To															
Adjacent Subareas	4.0	3.0	9.0	7.0	11.0	1260.0	1500.0	2000.0	2000.0	2000.0	6.9	6.1	24.5	19.0	29.9
Confined Aquifer	5.0	205.0	300.0	91.0	189.0	1260.0	1500.0	2000.0	2000.0	2000.0	8.6	417.9	815.5	247.4	513.8
TOTAL OUTFLOW FROM SUBSURFACE	258.7	637.0	537.8	531.7	548.2						525.1	1065.0	1113.7	1594.4	1501.2
INFLOW SUMMARY															
-SURFACE	795.7	2006.4	2119.7	1848.4	2868.2						816.5	1264.3	994.0	2054.7	1671.3
-SUBSURFACE	254.3	639.0	562.6	621.8	735.0						519.1	1175.4	1780.1	2942.7	2583.5
OUTFLOW SUMMARY															
-SURFACE	795.7	2006.4	2119.7	1848.4	2868.2						852.5	1478.3	1771.0	2950.7	2570.3
-SUBSURFACE	258.7	637.0	537.8	531.7	548.2						525.1	1065.0	1113.7	1594.4	1501.2
CHANGE IN STORAGE (ROOT ZONE)	0.0	0.0	0.0	0.0	0.0						-36.0	-214.0	-777.0	-896.0	-899.0
CHANGE IN STORAGE (UNCONFINED)	-4.4	1.9	24.7	90.1	186.8						-6.0	110.4	666.4	1348.3	1082.3

Appendix C

FIGURES

Note to Reader: The following figures are based on the reconnaissance-level hydrologic and salt budgets presented in the body of the report. They are intended to illustrate existing average annual conditions in each of the five planning subareas.

FIGURE C-1
PRESENT AVERAGE ANNUAL WATER AND SALT BALANCE
NORTHERN SUBAREA



C-1

CH2M HILL

FIGURE C-2
PRESENT AVERAGE ANNUAL WATER AND SALT BALANCE
GRASSLANDS SUBAREA

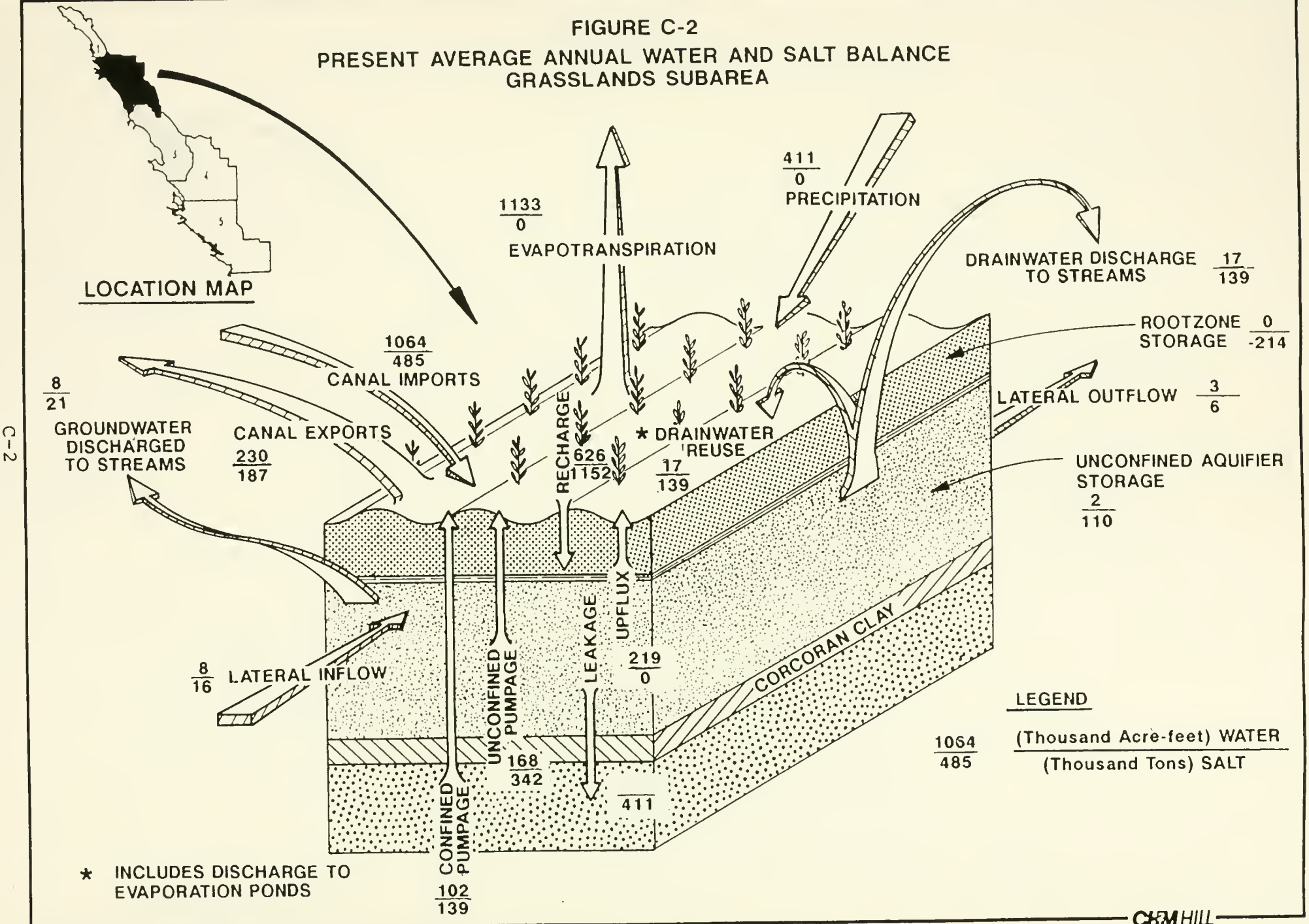


FIGURE C-3
PRESENT AVERAGE ANNUAL WATER AND SALT BALANCE
WESTLANDS SUBAREA

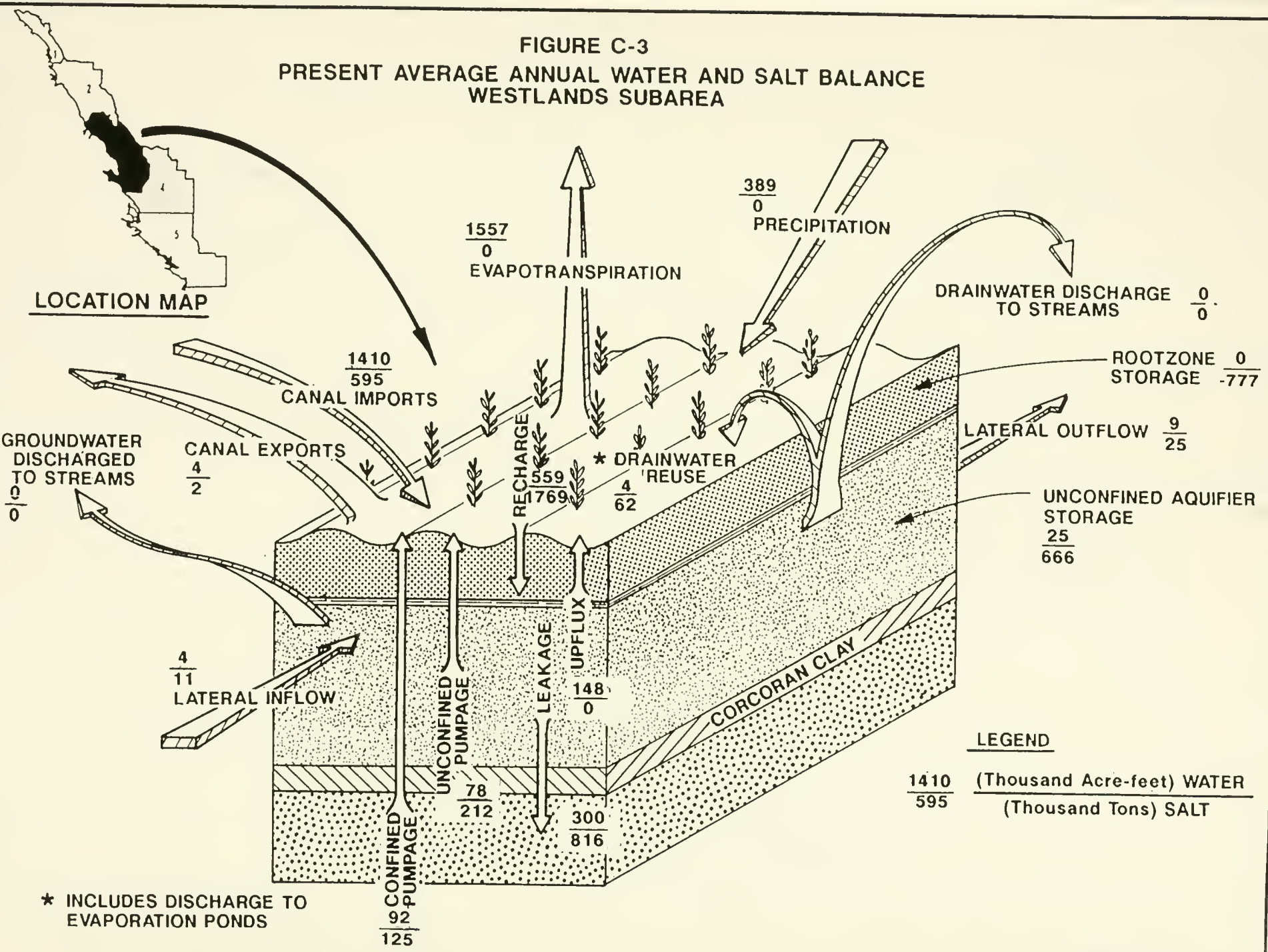
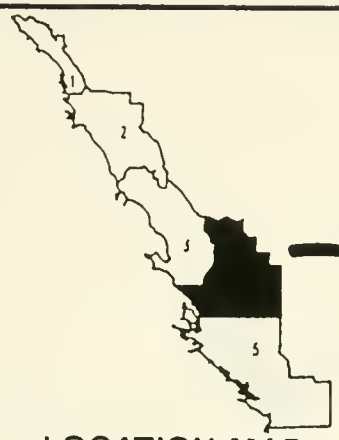


FIGURE C-4
PRESENT AVERAGE ANNUAL WATER AND SALT BALANCE
TULARE SUBAREA



LOCATION MAP

1254 / 0
EVAPOTRANSPIRATION

402 / 0
PRECIPITATION

DRAINWATER DISCHARGE TO STREAMS 0 / 0

ROOTZONE STORAGE 0 / -896

605 / 172
CANAL IMPORTS

CANAL EXPORTS 5 / 77

GROUNDWATER DISCHARGED TO STREAMS 4 / 77

RECHARGE 590 / 2873

* DRAINWATER REUSE 38 / 802

LATERAL OUTFLOW 7 / 19

UNCONFINED AQUIFER STORAGE 90 / 1348

19 / 52 LATERAL INFLOW

UPFLUX 227 / 0

LEAKAGE

UNCONFINED PUMPAGE 165 / 448

78 / 230

CORCORAN CLAY

CONFINED PUMPAGE 408 / 554

LEGEND

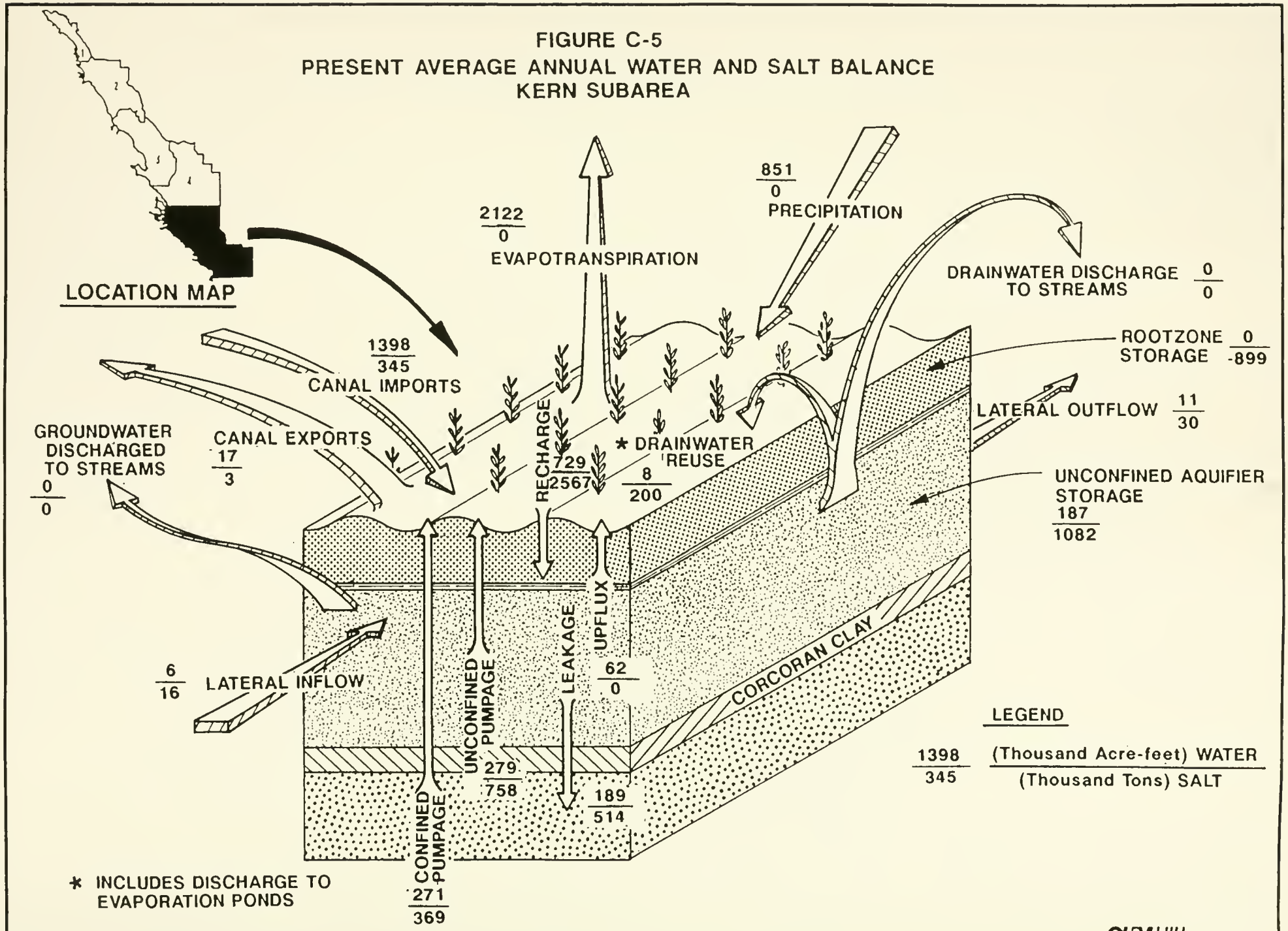
605 / 172 (Thousand Acre-feet) WATER / (Thousand Tons) SALT

* INCLUDES DISCHARGE TO EVAPORATION PONDS

C-4

CH2M HILL

FIGURE C-5
PRESENT AVERAGE ANNUAL WATER AND SALT BALANCE
KERN SUBAREA



P00001874